

# **PROMETHEUS UNCHAINED: THE RMA AND ITS AFFECT ON FUTURE TACTICAL COMMUNICATIONS SITE SELECTION**

**A MONOGRAPH  
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## ABSTRACT

PROMETHEUS UNCHAINED: THE RMA AND ITS AFFECT ON FUTURE TACTICAL COMMUNICATIONS SITE SELECTION by MAJ Daniel R. Kestle, USA, 56 pages.

This monograph addresses the feasibility of continuing to rely on the high ground for tactical communications site employment in the future. Current communications site selection is based on well founded communications principles, technological constraints, and warfighting methodologies. However, the US military is in the throes of debate over the fundamental characteristics of future warfare. At the center of this discussion is the concept of the "Revolution in Military Affairs" (RMA). The RMA stands to significantly alter warfighting methodology. The dominant driver for this phenomenon is technology. This is a two fold challenge to tactical communications providers of the future. Tactical communicators must be capable of both leveraging technology to support the warfighter's methods and employing these technologies to survive the rigors of the future battlefield. Accordingly, this monograph examines the affect the RMA may have on future tactical communications site selection.

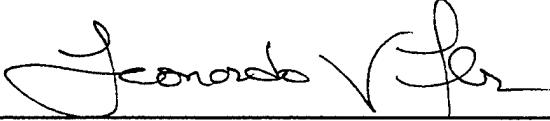
This analysis examines the historical development of military communications and the ramifications of the RMA on tactical communications site selection. After establishing and validating communications principles, the ability to provide the critical communications principle of continuity is examined for both historical RMAs and the future as projected by the current RMA. The four imperatives of continuity are connectivity, survivability, reliability, and redundancy. The analysis suggests that establishing tactical communications sites on high ground has historically enhanced, and will continue to enhance connectivity, reliability, and redundancy. However, whereas in the past, communications survivability on the high ground was relatively assured, analysis suggests a decrease in survivability on the future battlefield. This is because of the increasing lethality of the battlefield. And although this analysis does not completely refute the use of high ground for communications in the future, it does indicate that a reduction in reliance on its use would be prudent.

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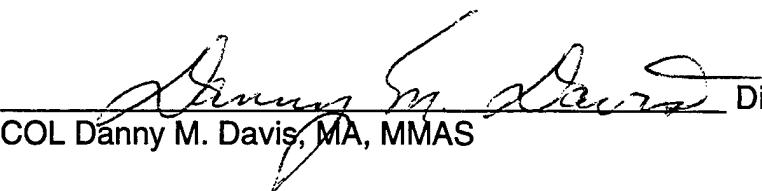
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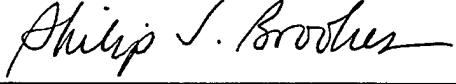
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## I. Introduction

Prometheus and his brother Epimetheus, both Titans, were tasked by the Gods to create man. This they did by making man of mud. Together the brothers were to provide man and all the creatures of the earth gifts to enhance their survivability. But there was a critical flaw in their logistics plan. When it came time to provide for man, the gifts were at zero balance. In an attempt to correct this deficiency, Prometheus rose to the heavens, stole fire from the Gods and gave it to man. For this sin, Prometheus was chained to Mount Caucasus where a vulture preyed on his ever regenerating liver. It took the strength of Hercules to break the chains and free Prometheus.<sup>1</sup>

Metaphorically, communications too is “chained” to high ground. Establishing communications on the high ground is a precept well rooted in the past. It is a concept that the US Signal Corps recognizes and has strong ties to.

Hanging in a hall of the Signal Corps Regimental Headquarters is a Don Stivers Civil War painting entitled “Signals from Little Round Top.” The painting depicts a wig-wag equipped Union Signal element in action atop Little Round Top during the Battle of Gettysburg. The detachment was credited with detecting the flanking movement of Confederate forces under General Longstreet. The performance of the Signal Element, immortalized in the painting, has been adopted by the Signal Corps Regiment as an official print.<sup>2</sup>

Little Round Top is but one example of the use of the high ground for communications. However, history is replete with further examples. The historical utility of the high ground is well founded. High ground improves line-of-sight, which

enhances visual, audio, and electromagnetic signaling. The physical attributes of the high ground enhances wave propagation, and therefore the range of communications transmission.

Signaleers understand the utility of the high ground and position communications sites on them as much as possible to take advantage of the propagation phenomenon. Technological changes are coming that may alter this perception. The significance of technological advances on communications employment depend on many variables and is difficult to predict. However, based on the general characteristics of the current Revolution in Military Affairs, one question immediately comes to mind: will it be feasible to continue to rely on the high ground for tactical communications site employment in the future? This is the fundamental question this monograph intends to answer.

Signals providers select sites that ensure communications continuity for the warfighter. **Continuity** encompasses the imperatives of **connectivity, reliability, redundancy, and survivability**. In the past, ensuring continuity was largely dependent on the use of high ground for communications. This basic tenet has shaped tactical communications site selection since armies first took to the field. However, as the US Army leans forward in anticipation of twenty-first century advanced technological warfare, the validity of this premise is in question.

To answer the research question of the high ground's relevance to tactical communications site selection in the future, this monograph examines the development of communications technologies in support of the warfighter and the utility of the high ground, and the general characteristics of past Revolutions in Military Affairs (RMA).

This examination establishes and validates the principles of communications and illustrates historical reliance on the high ground to support these principles. In addition, this examination draws parallels between historical and the current RMA to determine if patterns exist. From there, a projection of future characteristics is plausible.

Once future characteristics of the current RMA are defined, an evaluation is presented that examines the high ground's utility in supporting the principle of **continuity** on the future battlefield. From this evaluation, technological innovations and doctrinal implications in the future become evident.

Answering the question of high ground's utility to tactical communications in the future is of interest to anyone who keys a radio. The question has particular consequences for the US Signal Corps. The Signal Corps has thus far been able to provide the tactical warfighter communications support under the auspices of **continuity**. However, will its current reliance on the high ground prove feasible on future battlefields as projected under the RMA? This question is critical to junior signal officers who are now learning the ways of communications in the tactical environment. Their ability to provide tactical communications support now, and be successful future communications planners and providers, hinges on understanding asset site location. Based on experience and technological asset parameters, signaleers know where to establish communications assets and why ("Get on the high ground to improve your line-of-sight!"). Will the RMA shatter this ingrained mental model?

The findings of this monograph suggest that signal site survivability is becoming more tenuous. This is due to the increase in technological advances in emitter detection and long-range precision strike weapons. Communications sites on high ground are

increasingly more easily detected and targeted. The implication is clear. To enhance tactical communications site survivability in the future reliance on the high ground should lessen.

## **II. Communications and the High Ground**

The critical activity for a signals provider is communications support to the warfighter. At the tactical level, communications assets must be in proximity, both hierarchically and spatially, to the commander. Proximity allows the commander to direct emplacement of assets to support his needs (i.e., connectivity to his forces). The relationship between connectivity to the forces and the physical location of communications assets is dynamic. It must be constantly monitored and adjusted. It is this relationship between the physical location of the communication assets and the support performance required that is of interest.

This chapter develops an understanding of the relationship—between where communications assets are and what capabilities these assets can provide—as it exists today. First, a brief examination of the evolution of communications assets should underscore the underpinnings of current communications support, specifically the capabilities communications provide commanders. Second, an analysis of the effects elevation has on communications should clarify why high ground plays an important role in the placement of communications assets. Both steps should, in turn, set the stage for the subsequent look into the future of communications and communications support.

### **The Evolution of Military Communications**

This section traces the foundations of current Signal Corps tactical communications site selection doctrine. At the conclusion of this section, tactical

communication principles will be understood. To accomplish this, three areas require examination. They are, in order: command and control (C2); the role of communication in C2; and the evolution of military communications. With historically derived principles of communications clear, the roots of current site selection doctrine should be more apparent. This will establish the baseline for discussing, in the subsequent section, the attainment of these principles.

Command and control, by its very name, indicates two activities. FM 101-5: *Staff Organizations and Operations* defines *command* as the authority and responsibility vested in a commander to lawfully exercise leadership over subordinates. It goes on to state that “*control* [emphasis added] is the promulgation of the commander’s decisions, guidance, and intent with subsequent supervision and adjustment of subordinate forces’ execution to ensure compliance with the commander’s intent.”<sup>3</sup> For a commander to successfully execute C2, he must develop a C2 *system* capable of assisting him in decision making and relaying his guidance.

The C2 system is not an end in itself. The commander tailors it to suit his needs. There are, however, five primary components to any C2 system. These are personnel, communications, equipment, facilities, and procedures.<sup>4</sup> It is clear that the C2 system is not solely reliant on the communications resource. However, communications is a critical link that enables a commander to control his forces. If a commander can not transmit information he can neither exercise authority nor convey his intent. Ergo, communications is a prime enabler of C2. Now that command and control, and the role communication plays in the process, are clear it is time to look at the evolution of military communication.

As stated, communications supports the warfighter. As such, it is the boon of the signal supporter to adapt available technologies to support the warfighter. Conversely, the environment of the conflict and the characteristics of battle shape the warfighter's needs. The following historical review illustrates the interplay between the characteristics of the evolution of battle and the ability of technological advances to keep pace.

In the days of old, the physical constraints of terrain and communications limited a commander's ability to control his force. What he could see he could influence. It was this line of sight (LOS) that gave impetus to the first communications systems.<sup>5</sup> Thus, tactical communications on the battlefields of antiquity reflected man's (the commander's) ingenuity to cope with his environment. Because of the relatively limited size of the battlefield, a commander used visual or audible signals to direct his forces. Visual devices included raised weapons, battle flags, unit identifiers (legion standards, personal pendants, colored uniforms, etc.), and signal torches. The drawback to visual cues is the haze, dust, and smoke that can easily obscure them. To supplement visual signaling, audible devices were used. Audible signaling included drums, trumpets, and voice commands. However, for tactical communications it is evident that receivers of the visual and audible signals had to be within eye-sight or ear-shot. In other words, there typically had to be an uninterrupted straight line of sight from transmitter to receiver. Therefore, the messenger was used to further augment these systems. In the melee, the messenger was often the only way to ensure two-way communications.<sup>6</sup>

The multiplicity of communications methods points to two communications principles—**continuity** and **versatility**. It was imperative that the commander be able to

relay instructions to his forces. Multiple methods ensure reliability, redundancy, and connectivity. Additionally, the mix of audio, visual, and messenger provide a flexible system capable of responding to the needs of the commander and battlefield conditions.

As the physical dimensions of the battlefield increased so did the demands on the commander's ability to control his forces. The complexity of the expanded battlefield gave rise to the integration of the technological capabilities of the society. The commander, in developing his C2 system, looked to existing technologies to augment his abilities.

A comparison between Napoleonic and Civil War C2 systems illustrates how technology extended the limits of the commander's ingenuity. Napoleon has been regaled for his development of the first modern staff; however, his communication devices were little changed from millennia before (e.g. the running messenger announcing the Greek victory at Marathon versus mounted messenger). So although his command apparatus was remarkably advanced his tactical communications system still relied on couriers—a feat he managed successfully.<sup>7</sup> In contrast the Civil War exemplifies the integration of advancements in communications technology coupled with a “modern” staff. Communications devices included semaphore flags, hot air balloon with message drop, and, most notable, the telegraph. The development of horse-drawn “telegraph trains” enabled wire runs of ten miles in four hours, facilitating the role of telegraph in linking the strategic to the operational level.<sup>8</sup> Although the bulk of tactical communications occurred via semaphore flag and messenger, the telegraph gave a glimpse of things to come.

This period, and the Civil War in particular, gave birth to a third principle of communications—**security**. Because of the expansion of the battlefield, and the need to link the tactical to the strategic level, there was an exponential increase in the number of signals devices as compared to previous battlefields. The need to ensure physical security of the resulting signal detachments, as well as information security, came to the forefront.

The next major strides in tactical communications appeared during World War I. The tactical level continued to rely on visual (e.g., flares), audible (e.g., whistles), and messengers. However, technological advances did allow the first employment of the telephone and tactical switchboards. Because of the static nature of trench warfare on the western front, this new communications technology proved successful. The more fluid nature of the German southern front proved more daunting to land-line communications. However, ingenuity and discipline allowed German signaleers to adapt to the pace.<sup>9</sup>

It is clear that the general characteristics of tactical communications, from antiquity through the early 1900's, were similar. Armies used both visual and audible signals extensively. This was possible because of the physical proximity of the commander. A commander could observe the greater part of his forces and was able to relay commands to them with the use of primitive signaling methods. Although modest gains in communications occurred during the later part of the 1800's and early 1900's, the bulky equipment was hard pressed to support the tactical commander. As forces became larger and more dispersed, and the battlefield more chaotic, a crises in tactical communications was coming to a head. The world's leading armies began to wrestle with the problem of providing communications support under these new dynamics.

The impetus for the next stage in communications evolution was two fold. First, the radical employment of fast moving mechanized forces was under development. And secondly, technological advances were necessary to establish an effective means for controlling these forces. The Germans were the first to succeed in both areas in adapting the *blitzkrieg* and the radio. It is probably no coincidence that early in his career Heinz Guderian, noted as the technical innovator of the *blitzkrieg*, was an assistant Signals Officer to the Headquarters of the German Fourth Army.<sup>10</sup> Guderian himself insisted that German tanks be equipped with the best command facilities.<sup>11</sup> Germany's versatile use of the radio to coordinate and control tactical formations (to include maneuver, air, and fire support) was not lost on the allies. The allies zealously strove to develop radios that were smaller and capable of increased range. Still, it was not until 1944 that the US Army fielded tactical radios capable of transmitting up to 100 miles.<sup>12</sup>

Development and adaptation of the radio to the battlefield continued throughout the mid 1900's. Some emphasis, although arguably not enough, was placed on the coordination of air and ground. But a different kind of war, Vietnam, would facilitate the next advances in combat communications.

Vietnam provided several challenges to the Signal Corps. These were manifest in the type of warfare (there was no perceivable front line), the terrain, an increase in the dispersion of forces, and the vital need to coordinate air support. The Signal Corps overcame these challenges with numerous and dispersed fixed stations, the advent of radio retransmission facilities, the ability to bridge tactical communications into both operational and strategic communications systems, and an increase in inter-service compatibility. The warfighter wanted reliable communications and he got it, at a price.

To ensure continuity, signal architects developed redundant systems. The communications network expanded from the traditional Frequency Modulated (FM) radio net to a complex intertwining of Amplitude Modulation (AM), Pulse Coded Modulation, tropospheric scatter (i.e., troposcatter), and the first appearance of satellite in support of combat operations. However, the majority of these systems were cumbersome and failed to provide the warfighter a flexible and adaptive system. There was a manning bill to pay, too. Due to the technical nature and dispersion of communications facilities, a large signal contingent was necessary. By the end of 1970, over four percent of the entire US armed forces (i.e., Army, Air Force, Navy, Marines) in sector were US Army Signal personnel.<sup>13</sup> These monolithic systems, and the associated manning requirements, proved to be insupportable under the restructuring of the Army in the 1970's and 80's.

Vietnam also taught an inverse lesson on the principles of communications. In the past, tactical communications devices had been relatively simple. Given a modicum of training, waving semaphore flags, blowing bugles, firing star clusters, and operating radios could be done by anyone. However, the complexity of incompatible tactical devices and networks during Vietnam proved daunting. A fourth principle of communications was rediscovered—**simplicity**. Ease of employment facilitates timely transmission of information. It is a principle the Signal Corps took to heart as they looked to the next evolution in communications.

The Army learned their lessons and learned them well from Vietnam. These lessons, in conjunction with the Soviet threat in Europe, were the impetus for AirLand Battle. And signal support would have to adapt. Although the Signal Corps was capable of installing redundant, reliable communications systems, its existing systems were not

agile enough to support the tactical warfighter. With the exception of combat radio, the tactical backbone communications system continued to be a ponderous, slow moving beast. A more agile system was sought, and subsequently found in the British and French armies.

The adaptation and evolution of the concept behind the British Ptarmigan and the French Resau Integre Transmissions Automatique (RITA) systems became what is today, the US Army's Mobile Subscriber Equipment (MSE) System. MSE is predicated on providing the warfighter a tactical communications system that is less man intensive, more easily displaced, and capable of providing on the move telephonic support (military cellular telephone). MSE supports both the tactical and operational level with telephone and combat radio interface, and provides connectivity to the strategic level. As MSE was evolving, so too was Tactical Satellite (TACSAT). Although TACSAT does not have the data capacity of the MSE system, its range capabilities allow it to function from the tactical to the strategic level. Thus, by 1990, the tactical commander was equipped with a complementary "signal triad" to support his C2 system. The triad consisted of combat net radio, MSE as his mobile telephone company for bulk traffic, and TACSAT for long distance connectivity to remote locations. In short, tactical communications met the four communications principles—**continuity, versatility, security, and simplicity**. This signal configuration received its trial-by-fire during the Gulf War and still exists today.

Two things are clear from this evolutionary review. First, communications technologies must adapt to support the warfighting technique. As an example, land-line is effective in static or slow moving situations, while radio is necessary for fast moving, dispersed forces. Secondly, the historically derived principles of communications are

sound. Communications must provide the warfighter a system that ensures **continuity, versatility, security, and simplicity**. The synergistic effect of these principles allows the commander to exercise command of his forces by providing a conduit for the transmission of his guidance. But what is the keystone to implementing these principles? It is the physical manifestation of the communication equipment on the ground. Typically that point on the ground is elevated. The next section examines the age old axiom of signal equipment emplacement—“get on the high ground.”

### **The High Ground**

High ground has historically offered the possessor an advantage. High ground is good. This is true for both the warfighter and the signaleer. This section validates the importance of the high ground for the warfighter and establishes the corresponding value to the signaleer.

The historical tactical advantage of occupying high ground is not debatable. From the Battle of Hastings in 1066 to the Battle for the Falklands, the value of the high ground is evident (Senlac Hill in the former and the mountains of Port Stanley in the latter)<sup>14</sup>. There are several advantages to high ground. But the common denominator among the majority of these advantages is line-of-sight. Elevated terrain extends one’s line-of-sight. Thus, the tactical commander on high ground reaps benefits in early target detection, tracking, and engagement. High ground to the historical commander meant more than just combat advantage though. High ground was critical to his command and control. It was in fact part of the “facilities” he used in exercising his C2 system.

From antiquity through the mid 1700's, command was dependent on the leader's ability to observe the battlefield and his forces. What he could see he could influence (observe, decide, and direct). Signals transmitted his decisions to his forces. Accordingly, a commander's signaling apparatus had to be in close proximity for responsiveness. Because the commander was on a hill top, facilitating observation of the battlefield, his signals system was on the hill top, too.

As the size of forces and their dispersion increased, a commander was no longer capable of surveying the entire battlefield. As an example, Frederick the Great was often able to exercise direct command of all his forces from a static location overlooking the battlefield. However, fifty years later, during the Jena Campaign, Napoleon was unable to observe the entire field of battle and take direct action.<sup>15</sup> Commanders were no longer capable of observing the depth and breadth of the battlefield. The migration of the commander away from direct observation (line-of-sight) of the battlefield and his forces created additional challenges to his signals system. The geographical displacement of the commander from his forces now hampered immediate transmission of information. This challenge to communications still exists today.

Through the late 1800's numerous improvements/inventions were put into practice to facilitate distance communications (see previous section). However, all tactical systems relied on one variable line-of-site (LOS). To transmit information over distance, the receiver had to be capable of visual or audio reception. To improve unobstructed LOS, transmission from elevation made sense.

Through the early 1900's, the reliance on high ground for communications had two significant drawbacks. First, because of susceptibility to enemy fires,

communications had to be positioned to the rear. Although this facilitated communications survivability, it promoted defensive operations. Moving communications assets forward to support the offense was time consuming. Secondly, displacing from high ground, even if in close proximity to the front, is a slow process. The need for a communication system to overcome these shortfalls was clear. The advent of the radio, for the most part, overcame these deficiencies. And, although wireless communications was first demonstrated 16 December 1842, it took until World War II, almost 100 years, before its appearance at the tactical level.

However, radio introduced other constraints. Radio emits an electromagnetic signal. In general, the range of the signal depends on the transmission frequency and the forward power of the radio. The electromagnetic signal travels like a wave on water. If you drop a pebble in a body of water, an omnidirectional (two dimensional on the water's surface) wave travels out from the point of impact. The wave starts out high and tapers at extremes from its origin. Dropping a larger rock initiates a larger wave which would travel farther. As vision can be blocked or obscured, so too can radio waves. If an obstruction exists in the water, the wave will somewhat wrap around the edges, but a clear deadspace is observed to the rear of the object. Someone at the edge of this obstruction would sense some of the wave, but one behind would sense nothing. Radio waves in the air propagate like the water model. Accordingly, the concept of LOS holds true for radio as it did for antiquity's audio and visual signaling systems. Once again, the ideal location for radio is one with no obstructions between the transmitter and the receiver—on high ground.<sup>16</sup>

Radio continues to be the workhorse of the US Army tactical communications. Today, it is found in every facet of the Army's tactical communications architecture. This architecture consists of four networks: Area Common User System (ACUS, installed via MSE), Combat Net Radio (CNR, tactical voice radio, typically SINCGARS), Army Data Distribution System (ADDS, a data network), and broadcast (typically transmit-only stations for position location/navigation, e.g., Global Positioning System).<sup>17</sup> *All of these systems rely on electromagnetic transmission via radio.* Radio performs optimally when positioned on high ground with minimal obstruction between the transmitter and the receiver.

### **Current Communication Site Selection Doctrine**

Doctrinal principles for the employment of signal assets to the warfighter is found in FM 24-1: *Signal Support in the AirLand Battle*. FM 24-1 states that the four principles of signal support are “continuity, security, versatility, and simplicity.”<sup>18</sup> **Continuity** encapsulates the ideas of survivability, reliability, redundancy, and connectivity. **Security** addresses both physical and informational. **Versatility** refers to flexibility and interoperability. And **simplicity** codifies ease of employment. Based on the previous historical review it is easy to understand the evolution of these principles. They make sense. The implementation of these principles, however, is more elusive.<sup>19</sup>

A thorough review of signal doctrine does not reveal a capstone document for successfully supporting the above principles. However, a general analysis of the technical characteristics of current tactical communications does point to an inherent keystone. To fully exploit the capabilities of signal assets, proper site selection is critical.

Where does a Signal leader go to find doctrine on signal site selection? They don't.

There is none. Perplexing though it seems, signal site selection, based on technical capabilities and warfighter needs, is enigmatic and is found in bits and pieces within eleven separate Field Manuals.<sup>20</sup>

However, a quick analysis reveals the rule-of-thumb in tactical communications site selection. The bulk of tactical communications is done with radio. Radio operates best when there is a clear LOS from transmitter to receiver. High ground improves the probability of a clear LOS. Ergo, positioning signal assets on high ground enhances communications.

All signal officers understand this principle and have ingrained it as a tenet to successful communications. Anyone who has been to the National Training Center (NTC) can attest to this truism. A Brigade Commander often positions his Tactical Operations Center (TOC) in a wadi for security. The result is high agitation for the signal personnel who attempt to elevate antennas to ensure a clear LOS to outlying forces. "Sir, if you could just place the TOC on top of that hill..."

## **Summary**

Commander's must craft their C2 system to meet their needs. The system must support the warfighting method and leverage available communication technologies. Tactical communications site selection is critical to both support the warfighter's methodology and to exploit technological capabilities. In general, the positioning factor for tactical communications devices from antiquity to today is the reliance on LOS. It is axiomatic that signal assets on high ground enhance LOS and thus communications.

Although current signal doctrine is very clear in stating the principles of signal support (i.e., **continuity, security, versatility, and simplicity**), there is no doctrine for tactical signal site selection with respect to technological capabilities. This monograph contends that, though a measurement (i.e., the principles) for successful communications exists, there is no published capstone doctrine to implement it. The previous review suggests that the keystone to supporting the communications principles is signal site selection. This is the critical point where communications manifest in support of the warfighter. Currently, the practice of tactical communication site selection is a function of experience and communication device capabilities. Experience and technological capability have effectively chained signal sites to the high ground. The next chapter examines future battlefield characteristics that may affect current tactical communications site selection.

### **III. The Revolution in Military Affairs**

Today there is a debate over exactly what a Revolution in Military Affairs (RMA) is and whether we are in the midst of one. For the purposes of this paper, the point is, in general, moot. The debate does, however, highlight two aspects that are critical to understanding tactical communications on the future battlefield. First, what the battlefield looks like—debate participants are trying to predict the nature of the future battlefield. And secondly, the perception of an RMA, whether real or imaginary, *is shaping our future forces today*. Warfighters of the future will have to adapt their C2 systems to communications equipment being procured now. Tactical communications in the future hinges on these two points: the general characteristics of the future battlefield and the technology's ability to respond to the warfighter's C2 needs. Both the environment and the warfighter's requirements will drive how communication support is executed in the future.

The aim of this chapter is to paint a picture of the technological aspect of this future battlefield. With a firm understanding of the environment communicators will operate in, and the technologies available to support the principles of communications, a subsequent evaluation between the past and future will be possible. To meet this end, this chapter reviews the definition of RMA, presents possible historical RMAs, synthesizes characteristics of the future battlefield, and concludes with a discussion on tactical communications under the auspices of RMA.

Throughout this chapter it is important to keep perspective on RMA implications for tactical communications. Communicators strive to implement the four principles of communications: continuity, security, versatility, and simplicity. **Continuity**, above all else, is the most important. Continuity entails **connectivity, survivability, reliability, and redundancy**.

### **What is an RMA**

There is much debate over the term RMA. To some, it has sweeping connotations indicating grand transformations.<sup>21</sup> To others it is deeply rooted in societal conflict between and among agrarian, industrial, and information “wave” societies.<sup>22</sup> However, for the purposes of this monograph, RMA is best described by Metz and Kievit who said, “The basic premise of the ...RMA is simple: throughout history, warfare usually developed in an evolutionary fashion, but occasionally ideas and inventions combined to propel dramatic and decisive change.”<sup>23</sup> In general, ideas are synonymous with conceptual changes in warfighting methodologies, and inventions connote technological advances.

Most authors agree that a true RMA reflects more than military changes. These changes can manifest themselves in social, political, or policy changes.<sup>24</sup> However, what is of interest is the fundamental change caused by an RMA and its subsequent impact on tactical communications. The RMA, by definition, implies changes in warfighting methodology and technology. These two changes will clearly have an impact on communications.

What other future changes will impact the communicator? No one can predict them with certainty, however, reviewing past RMA characteristics can provide a benchmark for future trends. With reasonable future trends in hand, it will be possible to evaluate current communications principles against future requirements.

### **Previous RMAs**

The five RMAs for review are the Roman Legion, Napoleonic Warfare, Needle-gun Warfare, *Blitzkrieg*, and Desert Storm.

**The Roman Legion.** Prior to the inception of the Roman Legion, the renown military formation was the Phalanx—meaning “roller.”<sup>25</sup> The phalanx, first developed by the Macedonians, consisted of infantrymen, called *hoplites*, on-line and at a depth of eight to sixteen men.<sup>26</sup> Greek terrain, which is unfavorable to the use of cavalry, provided the impetus for this development. The *hoplites* were well trained, armored, and armed with shields, short swords, spears, and pikes. With twenty-one foot pikes, the appearance of the phalanx on the battlefield could be likened to a porcupine. The density, up to 10,000 men, of this formation provided mass and staying power.<sup>27</sup> If attacked by arrow, shields could be raised about the entire formation. If attacked by cavalry, the pikes could be lowered to defeat the horse at a distance from the leading line of men. In the close fight, the short sword did most of the work, however, spears allowed second and third line forces to participate in the fray.

The density of the phalanx made command and control of this formation relatively easy. After the commander had surveyed the battlefield, he had only to pick terrain favorable to his plan, and march his forces in mass to that location (for a

description of tactical communications during this time see Chapter II). The phalanx appeared to be unstoppable. In fact, the formation enjoyed dominance on the battlefield for over 400 years. However, the phalanx did have an Achilles heel. Its mass restricted mobility and flexibility.

The Greek phalanx, because of its success, was adopted throughout the north and northeastern Mediterranean. Although the formation's exploitation is best illustrated by the conquests of Alexander the Great, it was also used by the Spartans, Hellenites, and the Romans, to name a few. The Romans achieved initial success with the phalanx by creating smaller phalanxes called *maniples*. However, untrustworthy troops had a tendency to reduce *maniple* intervals with the effect of forming a Greek phalanx of old.<sup>28</sup> The impetus for the change to the phalanx was a crushing defeat suffered by the Romans. In 105 BC, a Roman army of 80,000, and employing the phalanx, was virtually annihilated by barbarians in the Battle of Arausio.<sup>29</sup> To rectify this, Marius of Rome, undertook the reform of the Roman army.

Marius instituted two sweeping and revolutionary changes. First, though accepting the general concept of the phalangial formation, he changed its fundamental organization. He established the cohort. A cohort consisted of eight to ten ranks of men, fifty across. The Marian legion consisted of ten cohorts arrayed in depth (typically three deep). This allowed more flexibility and control while in contact or moving to contact. A phalanxed army, moving in mass, could easily be flanked by this new organization. Secondly, Marius increased the interval between the men. Whereas men in the phalanx were shoulder to shoulder, Marius increased the interval between men to three feet while maneuvering, and six feet for close combat. This had the effect of enhancing mobility

and flexibility, reducing vulnerability to arrow attack, and providing combatants with ample room to weld their sword.<sup>30</sup> In comparison, only first rank men of the phalanx were capable of engaging with the sword. And, because of their density, they were capable of only short thrusting. By increasing Roman combatant surface area, Marius was able to get more troops effectively into the fight. Executing these changes in the face of phalanx was not only revolutionary, but gutsy!

The death of phalanx warfare was sealed during the battles of Cynoscephalae and Pydna. Both battles were cases of the Roman legion meeting the Macedonian phalanx. In both cases, the legion was victorious.<sup>31</sup>

The ramifications to tactical communications are subtle. In both the phalanx and the legion, communications were primarily visual, audio, and messenger. This was possible because of the limited rate of advancing forces and the scope of the battlefield. Specifically, the pace of infantrymen and the commander's LOS supported visual, audio and messenger communications. However, with the phalanx, only one communications receiver needed to get the message. With a single focal point it was relatively easy to ensure tactical communications **connectivity, survivability, reliability, and redundancy**. Conversely, the revolutionary aspect of the legion increased the number of receivers tenfold (i.e., ten cohorts requiring control as opposed to a single phalanx). Additionally, cohort mobility and troop intervals increased dispersion of these receivers on the battlefield. Both of these increases in the number of receivers and in dispersion placed a premium on **connectivity, reliability, and redundancy**.

Napoleonic Warfare. Up until the late 1700's very little had changed in the conduct of war. Armies, largely infantry, remained small and were led by commanders

who could position themselves to observe the entire battlefield. It was the agrarian nature of states that constrained the size of armies. States could field armies up to a size that was commensurate with the state's ability to equip, sustain, and control them. The relatively small size of armies had two affects. First, fear of losing the army limited grand objectives to the occupation of strategic and political centers.<sup>32</sup> Typically, in achieving those objectives, under no circumstances was the existence of the army to be jeopardized. And secondly, commanders were literally able to observe all of their forces on the battlefield. In this manner of warfare, battles were often concluded by merely attaining a position of advantage. A commander, perceiving his position as untenable, could retire his forces and possibly lose the conflict without ever becoming engaged. But the dawn of the industrial revolution, coupled with technological, social, and political changes was to forever shatter this concept of war.

The predominant characteristics of the Napoleonic RMA were threefold: technological, organizational, and strategic. First, technological advances had a profound impact on state infrastructure, weaponry, and populations. Of particular note were the improvements in roads, canals, and cartography which enhanced a state's ability to move forces. As the infrastructure improved, so did the economy. With a robust economy, population densities increased. To an army, population means manpower. Additionally, food to support a large population could be easily requisitioned for military purposes.

The second characteristic, organization, was an outgrowth of societal changes and control requirements. The French Revolution enflamed a nationalistic spirit. The *Grande Armee* would not lack for volunteers. This fact alone was revolutionary. Whereas previous armies rarely passed 80,000, the French were capable of fielding an

army 150,000 strong.<sup>33</sup> The ability to control a heretofore unwieldy behemoth was rooted in concept of the corps. By 1805, the French army had eight numbered corps. Each corps consisted of 20,000 to 30,000 men, and was organized as a mini-army. In this manner, a corps could conduct stand-alone operations for several days, or because of uniformity, be exchanged one for the other.<sup>34</sup>

The last characteristic of this RMA was one of fundamental strategy. Napoleon's strategy was to seek out a general battle in which he could decisively destroy the enemy's force. This was a marked departure from the previous concept where armies, least of all, sought heated engagements.

The Napoleonic RMA arose from the synergistic effect of social, political, technological, and organizational change. Napoleon was at the right time and place, and had the brilliance to be the catalyst for this revolution. His ability to command and control the largest army in history (at that time), was testament to his prowess. In short, the Napoleonic RMA, at the door of the industrial revolution, was the precursor to modern warfare and nations in arms.

The implications for tactical communications were significantly different at the juncture of this RMA. In general, Napoleonic warfare was characterized by large forces advancing on separate axes. This often created several battlefields (e.g. Jena and Auerstadt). A commander was no longer capable of observing and directing all of his forces on the battlefield. At the tactical level, a commander could now easily be a terrain feature behind his forces. Although tactical communications still relied on visual, audio, and messenger, as did the Roman legions, the challenges to the principle of **continuity** had increased in magnitude. Whereas rates of advance and messenger service still moved

at the pace of the infantryman or the horse, force dispersion had increased distances dramatically. As an example, just prior to the Battle of Jena-Auerstadt, the wings of Napoleon's force were separated by forty miles.<sup>35</sup> On horse back, and maintaining a five and a half mile per hour pace, it would take over seven hours to pass information from one wing to the other. Using tactical communications technology that was virtually unchanged in over 2000 years, it is remarkable that Napoleon was as successful as he was.

Needle-gun War. Needle-gun warfare typified the impact of the industrial revolution on warfare. It encompassed warfare in the later part of the 19th century, specifically the American Civil War and the Franco-Prussian Wars.<sup>36</sup> These wars exemplified the conduct of war in the full swing of the industrial revolution.

The industrial revolution's impact on warfare was primarily technological. Most noteworthy were advances in weaponry, transportation, and communications. The introduction of first rifled weapons and then firing-pin (needle gun) rifles enhanced rates of fire, range, and accuracy. Although these advances increased lethality, the advent of the needle gun also allowed infantrymen to reload from the prone position, thus reducing exposure. The dominant transportation advance was that of the railroad. The railroad enabled nations to mobilize vast numbers of men and transport them tremendous distances in a short time. Expansion of the railroad facilitated the development of advanced communications. Of note was the telegraph. The telegraph, initially strung along railroad beds, was used to control the massive transportation effort. Success of the telegraph quickly led to military applications (see Chapter II).

Arguably the most revolutionary aspect of this period was mobility. Never before could such large numbers of men and supplies be moved so quickly, so far. As mobility increased, so did dispersion. It is axiomatic that commanders, to be successful, must maintain C2 of their forces. Increasing force dispersion strains a commander's C2 system's ability to maintain **continuity**. It was the telegraph, as a corollary to the railroad, that enabled C2 systems to function. Those who understood and exploited this concept were successful (e.g., Grant's Vicksburg Campaign and Helmut von Moltke's campaign against Austria).

Ramifications to tactical communications were twofold. First, advances in weaponry brought signals detachments into range of enemy guns. This is the first historical instance where communications **survivability** was seriously in jeopardy. The cause of this, in large part, was a result of the second impact of the period—dispersion. As forces gained mobility, their dispersion naturally ensued. To compensate for this, communications providers improved **connectivity** by establishing elaborate visual relay systems. Because tactical commanders could be a terrain feature or two behind their forces, signals wig-wag detachments were positioned on interim high ground to enhance connectivity.

High ground along the front was typically in weapons range of the enemy. Tactical communications sites positioned on the high ground were increasingly at risk. During the American Civil War, slow rates of advance tended to fix communications sites and further exposed them to enemy fire. To offset this risk, messengers were relied upon to provide redundancy. In contrast, the Prussians, under the direction of Moltke, overcame the threat to communications **survivability** by relying on force mobility. A

moving target is more difficult to hit. Although this improved **survivability**, it stressed other **continuity** imperatives that would not be resolved until the next RMA.

*Blitzkrieg*. Some argue that World War I was an RMA.<sup>37</sup> And, indeed, in it the industrial revolution was harnessed as never before. Advances in production made possible the equipping, arming, and transportation of multimillion man armies. There were also advances in tactical communications. Most notable were the land-line telephone and, to a lesser extent, the radio. However, warfare as a whole, in this author's opinion, experienced no significant revolutionary change. The static and attrition nature of war during WW I indicated devolution. In this environment, communications principles were relatively easy to support from the communications provider's perspective. Conversely, the *blitzkrieg*, synthesized several changes of the day and resulted in a clear departure from previous warfare methods. The implications to tactical communications were profound.

The static nature of WW I was costly, in both manpower and materiel, and indecisive. On all counts, Germany, least of all, could afford a rematch under these circumstances. To gain victory, a radical departure from this form of war was necessary. The Germans were the first to advance military art under the auspices of the *blitzkrieg*—lightning war.<sup>38</sup>

*Blitzkrieg* is predicated on speed and force. As such, it relies heavily on mechanization and an integrated arms concept (airpower, fire support, and maneuver). The industrial revolution, at its peak, was capable of providing the mechanical tools in support of this concept. Specifically, these were advances in weaponry, the internal combustion engine, and the radio. Weaponry improvements included airplanes, tanks,

and rockets, to name a few. These provided the *blitzkrieg* a strike force punch. Perfection of the internal combustion engine had two primary implications. First, tactical commanders were freed from reliance on static rail lines for transportation and supply. Secondly, this new found freedom of maneuver restored mobility and tactical art to the battlefield. However, as seen in previous RMAs, mobility leads to dispersion. The Germans overcame this by decentralizing command and fully exploiting the capabilities of the radio. Radio provided instantaneous two-way communications to all levels of war. The combination of advances in mechanization and communications gave the Germans a flexibility and speed heretofore unparalleled. Coupled with an integrated arms doctrine, they were virtually unstoppable during the first years of the war.

The revolution of the German *blitzkrieg* concept shattered all previous paradigms on the conduct of war. The success came from the ability to harness existing technologies, adapt military doctrine, and innovate C2. These enabled the Germans to field a force that was mobile, flexible, and powerful.

The most significant implication for tactical communications during this RMA directly resulted from the increase in tactical mobility. Mobility tended to increase: unit dispersion and number of receivers, range to receivers, and risk to signals sites. The prevalence of the radio on the battlefield, for the most part, did enhance the capability of the signals provider to support the principle of **continuity**. However, the ability to support the imperative of **survivability** dropped significantly.

During WW I, fixed troop units promoted fixed communications. At the tactical level, these were typically entrenched land-line telephones. **Survivability** of these assets was ensured by positioning the vulnerable switches well to the rear. The *blitzkrieg*

yanked the signaleers from the safety of the rear. Communications assets would now have to travel with fast moving mobile forces. Because of the radio's reliance on line-of-sight, isolated relays would have to be established along interim high ground to ensure connectivity with higher echelons. Proximity to the close fight and isolation, while in relay/retransmission mode, lessened the **survivability** of these communications assets.

Although in its infancy, another threat to communications **survivability** was looming on the horizon. This was the increasing sophistication of radio direction finding. During WW II, this was not a significant threat to the tactical commander; although triangulation was relatively simple, bringing fires to bear quickly upon identified emitters was another matter. Mobility, although stressing the C2 system, did provide communications a modicum of security. However, the potential of advances in electromagnetic signature detection and location were becoming apparent.

Desert Storm. TRADOC PAM 525-5 states that Desert Storm (DS) epitomizes the current RMA and offers a glimpse of the future conduct of war.<sup>39</sup> However, debate over exactly what the RMA is continues to rage. At a philosophical level, the debate centers around the Tofflers' assertion that we are in the midst of the creation of "third wave warfare" (information based warfare) and that DS was an indicator of things to come.<sup>40</sup> At the muddy-boots level, "innovations in technology and doctrine" are the crux of the RMA debate.<sup>41</sup> However, for the purposes of this monograph, there are three characteristics of interest. These are the profusion of sophisticated technology on the battlefield, the joint and combined nature of the conflict, and increasing lethality.

Technological advances, and an increased reliance on them, were evident in every aspect of the war. From weaponry to communications to emitter detection, the theater

was packed with advanced gadgetry. The bulk of these advances rely on the electromagnetic spectrum. Whether relaying targeting data to precision weapons, or simply transmitting requests for supply, the preponderance of the systems employed during DS used radio.

The second characteristic of DS, its level of joint and combined operation, has no precursor. If nothing else, DS validated the US's ability to integrate different doctrines, equipment, and technologies into one effective fighting force. Given the distances and number of forces involved, the feat was nothing less than astounding. In this environment, a tactical commander could find himself operating with British land forces and relying on the Saudi Air Force for close air support. The intricacies of accomplishing this, although perhaps not apparent to the layman, are immense.

Finally, DS illustrated the increasing lethality of the battlefield. This is demonstrated by the elimination, or negation, of the traditional concept of the deep, close, and rear battle. As Macgregor states, to the Iraqi's it seemed "the deep, close, and rear battles were compressed into one seamless continuous attack."<sup>42</sup> This was a departure from previous conflicts where opponents have had safe havens. The pace, depth, and breadth of the coalition attack denied the Iraqi's any respite anywhere. The US was able to accomplish this with advances in weaponry, C2 sophistication, and innovations in doctrine.

To the tactical communicator, the implications of DS are threefold. First, there appears to be an ever increasing sophistication of communications technologies. Presumably, these advances will continue to improve the communications provider's ability to implement the principle of **continuity**. On the other side of the technological

coin, the enemy's ability to detect transmitters will also improve. Secondly, future conflict will be a more joint and combined affair. This suggests potential problems in equipment integration and network management. And finally, battlefield lethality is on the rise. This translates directly to a decrease in communications site **survivability**.

Although these three characterize a continuing challenge to the communications providers' ability to support the principle of continuity, there is good news. Technological advances are, thus far, capable of ensuring **connectivity, reliability, and redundancy** over vast distances and between international forces. The bad news for communicators is the specter of lethality. As emitter detection improves, and weapon precision and range increase, **survivability** of communications sites declines.

### **RMA Trends**

Several RMA trends are apparent from the previous review. It is important to be cognizant of these as we look towards communications on the future battlefield. In general, previous RMAs indicate increases in the following: force dispersion, mobility, reliance on technology, emitter detection, and lethality. Technological advances appear to be capable of keeping pace with, and ensuring, **continuity** in the face of these first four. However, countering lethality remains elusive. The next section examines the implications of these characteristics on future communications.

### **Implications for Future Communications**

The principles of communications are immutable. The equipment and environment in which future communicators will have to execute them is not. The RMA

suggests significant changes are afoot in technology and that increasing lethality is a predominant characteristic of the future battlefield. Communicators should begin to come to terms now with both the employment and emplacement of advanced technologies in this environment. Accordingly, this section focuses on leveraging technology and enhancing **survivability** on the future battlefield. Because of the myriad of advances in communications, a review of three will give a general idea of where technologies are heading. These are: the Unmanned Aerial Vehicle (UAV), burst communications, and commercial satellite. Proper employment of these technologies has direct implications on **survivability**.

Currently, a US Army heavy division employs roughly 10,700 radio emitters and operates in a 45 kilometer by 70 kilometer area.<sup>43</sup> Given the rapid advances in technology, dispersion (caused by mobility and lethality), and the increasing reliance on information gathering and transfer, it is conceivable that the number of emitters in a heavy division may double. In no way, shape, or form, will high ground accommodate emplacement of all of these devices to enhance LOS.

One solution to this problem is to use a UAV to act as “virtual” high ground for emitters. Current tests on the medium altitude Predator reveal that the concept is not merely plausible, but practical. The Predator operates up to altitudes of 45,000 feet and can loiter for up to 40 hours. Test communications packages being flown provide thirteen spot beams covering an area of 193 kilometers by 113 kilometers. When flying at 45,000 feet, the Predator is capable of communications with the ground at up to a range of roughly 240 nautical miles.<sup>44</sup> Future UAV communications packages, referred to as

HAE UCN (High-Altitude-Endurance UAV Communications Node), will be able to carry multiband, multimode payloads, and be capable of crosslinking between aircraft.<sup>45</sup>

So what does this mean for signal site selection and survivability in the future?

Lots of emitters mean lots of electromagnetic signatures. Electromagnetic signatures on a technologically sophisticated and lethal battlefield is bad. Positioning an emitter on high ground can be likened to a light-house, except the beacon doesn't warn of disaster—it invites it. The use of the HAE UCN has the potential to negate this affect. With proper employment, the HAE UCNs will allow the possible plethora of communications emitters to position in low lying ground, using the high ground to mask electromagnetic signatures.

Another solution is to develop radio burst communications technology to support conventional force operations. The positive side of burst communications is the reduced duration of transmission. By reducing the duration of transmission, the probability of intercept (POI) drops to negligible levels. There are, however, two drawbacks to burst communications. First, current burst communications devices do not allow for simultaneous two-way traffic. The duration of the transmission is simply too short (i.e., milliseconds) to conduct intelligible voice communications. Secondly, burst communications devices are radios. As such they are bound by the physics of electromagnetic wave propagation and their performance is still related to unobstructed LOS. So, although electronic detection is negated, the emitter still functions best when positioned on high ground. In the face of increasing lethality, high ground does not seem like a good place to be on the future battlefield.

One possible use for burst communications is friendly vehicle tracking. Currently, some commercial trucking companies are using meteor burst communications to track trucks and containers. This concept could easily be adapted to military use. Meteor burst communications relies on naturally occurring meteors to act as signal retransmitters. As meteors vaporize in the upper atmosphere, they create ionized trails. These trails literally retransmit radio signals. Thus, military vehicles on the move could transmit short messages (e.g., unit identification and gird) to a division or corps master station, that tracks all friendly movements. The advantage of this system is the obviation of the use of the high ground. Meteor trails create a virtual, albeit short lived, high ground.<sup>46</sup>

Finally, another possible solution to increasing survivability on the future battlefield is exploitation of satellite communications. The use of satellite communications at the tactical level made its first appearance during DS. However, the number of available channels and devices was limited. As commercial satellite constellations begin to proliferate and provide global coverage (e.g. Iridium), their military applications become unlimited. It is conceivable that hand-held satellite communications devices could be found at the squad level in the not-too-distant future.<sup>47</sup>

A thorough review of all technological advances to tactical communications would take a lifetime. However, the common nature of these advances is easily discernible. They are all attempts to enhance the principles of communications in support of the warfighter. The three advances mentioned above point to one aspect of these principles—**survivability**. In each case, the intent is to have electromagnetic emissions propagate upward to a relay/retransmission platform. The implications are twofold.

First, by reducing horizontal emissions, the probability of enemy detection and interception drops to imperceptible levels. And secondly, vertical LOS enhances defilade transmission. The warfighter will be able to hide his TOC in virtually any terrain and still be able to communicate. Both enhance the **survivability** of communications sites.

## IV. Conclusion

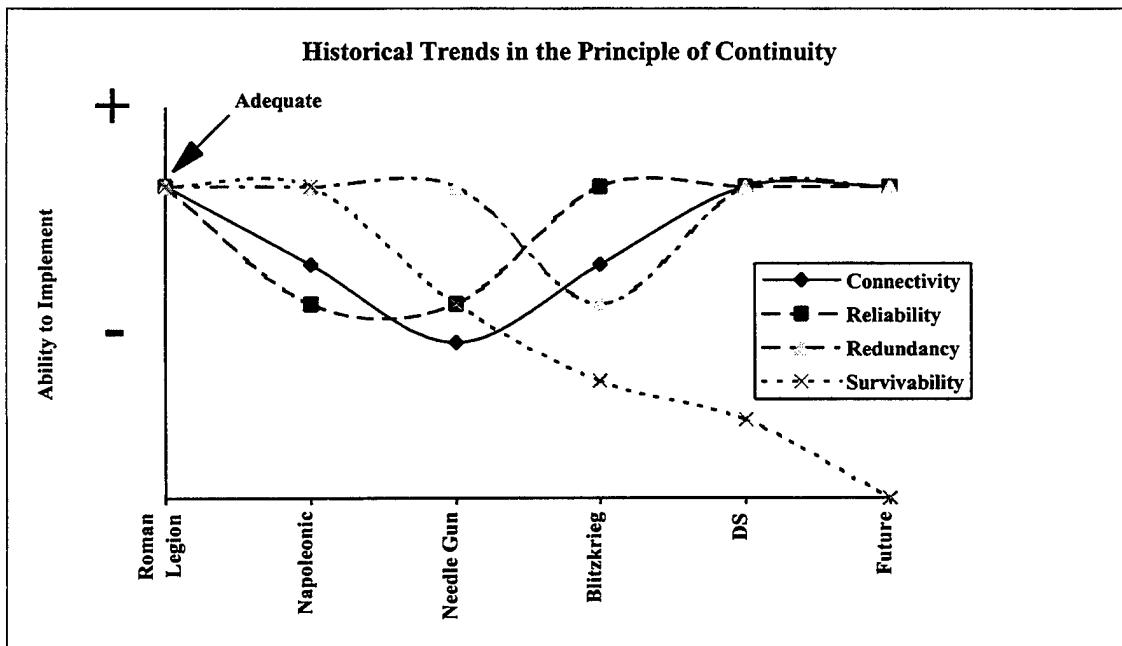
### Into the Future

Communications support is based on four principles: continuity, security, versatility, and simplicity. To be successful, communications above all else, must provide **continuity**. Continuity, as defined earlier, encompasses **connectivity**, **reliability**, **redundancy**, and **survivability**. Connectivity allows a commander to transmit information to, and enables the C2 of, his forces. If one provides for communications security, versatility, and simplicity, but not for continuity, are the communications successful? No!

**Connectivity** is dependent upon technology. From antiquity through the early 1900s, tactical communications technology operated in a two-dimensional environment and was limited to the receiver's physical capabilities (i.e., visual and audio acuity). During this time, devices were designed and employed to enhance the transmission of information over horizontal linear distance; transmission distances were limited by human capacity to recognize visual and audio signals. The advent of the radio increased connectivity range and allowed for the fuller integration of a third dimension to the battlefield—the air. All of these transmission means (visual, audio, and electromagnetic) are bound by the physics of wave propagation. Unobstructed wave propagation, clear line-of-sight, facilitates transmission. Accordingly, establishing signals assets on high ground enhances LOS.

In the past, employment of communications assets on high ground maximized technological capabilities. However, as pointed out in Chapter III, the challenge of the future lies in continuing to provide **continuity** on an increasingly lethal battlefield. Given this future environment, is reliance on the high ground as imperative in the future as in the past? To find out, it is necessary to evaluate the principle of **continuity**, and its four imperatives, in view of the historical RMAs and attempt to project this into the future.

The common communications variable throughout each previous RMA is the use of the high ground. High ground has always been used to enhance **continuity**. To determine high ground's utility in the future, this evaluation assumes its continued use. The following graph provides a qualitative illustration of each RMA's ability to implement the imperatives of continuity through the use of the high ground.



**Connectivity.** Communications connectivity to forces was perfect in the times of antiquity and during DS. In the former, a commander had LOS with all of his forces because of limited size of the battlefield. In the latter, technological advances ensured connectivity. In comparison to antiquity and DS, connectivity was less adequate from Napoleonic warfare to the *blitzkrieg*. Nadir during the needle gun era, reflects the effects of increasing force mobility and dispersion and the inability of communications technology to keep pace. The brief examination of future advances presented in Chapter III lend credence to the assertion that technology's ability to maintain connectivity with fast moving and widely dispersed forces, as demonstrated during DS, will continue into the future.

**Reliability.** As with connectivity, reliability during antiquity was based on proximity to the commander and the system used. Tactical communication under the immediate control of the commander were responsive and simple. Increasing force mobility and dispersion, and tactical communication's limited evolution resulted in a degradation in reliability during the Napoleonic and needle gun eras. Antiquated message modes—audio, visual, and messenger—were still the primary means for tactical communications. These simplistic systems enhance reliability, though, because of mobility and dispersion, not to the same degree as during antiquity. The advent of the radio during the *blitzkrieg* era restored communications reliability to the battlefield. Although an analog device, and arguably tenuous at times, radio provided a responsive real-time tool to the warfighter. Advances in digital communications clearly provide reliability, as demonstrated during DS. It is plausible that as communications technologies advance, reliability will continue to improve in the future.

**Redundancy.** Redundancy from the Roman legion through the era of the needle gun was adequate and unchanged. In all cases, audio, visual, and messenger systems were used for tactical communications. This triad provided the commander redundant communications means. Conversely, the exponential increase in mobility and dispersion, and the infancy of the tactical radio, reflect less adequate redundancy during the *blitzkrieg*. The Germans overcame this by decentralizing C2. However, the point remains valid—if industrial age communications (radio) were lost, agrarian age techniques (audio, visual, messenger) could not effectively overcome the shortfall. Technological innovations and the maturing of the radio restored redundancy to the battlefield as seen in DS. During DS the warfighter had available to him, in addition to the agrarian age techniques, AM, FM, MSE, and TACSAT. The continuing proliferation of varying types of communications devices suggests that redundancy will remain well in hand.

**Survivability.** The implications of survivability on the future battlefield are perhaps the most difficult to glean, but analysis is revealing. In general, survivability of communications sites has continued to degrade. During antiquity, communication site location ensured **survivability**. Communications were in close proximity to the commander. Commanders were typically located in a position of relative safety. Accordingly, the communications system was survivable. As force mobility and dispersion increased, communications sites have had to locate either directly with combat units or, due to LOS requirements, on high ground in order to ensure continuity. In either case, communications sites have become more vulnerable. Technological advances in emitter detection and targeting have exacerbated this phenomenon. Desert Storm is a

case in point—Iraqi communications sites were easily detected and targeted. It makes sense that this trend will continue into the future. Thus, the adequacy of **survivability**, more than all other continuity imperatives, is in question on the future battlefield.

### **Findings and Implications**

No one can foresee the future. However, based on the above analysis, one can discern certain plausible trends. In general, it is clear that tactical communicators strive to support the principles of communications. Of these principles, **continuity is the critical task** for a communications provider. Of the four imperatives of continuity, technological advances appear to directly improve three: **connectivity, reliability, and redundancy**. However, technology alone can not improve the fourth imperative of continuity, **survivability**. This is due to the immutable physics of wave propagation. Waves have always, and will always, travel best via unobstructed LOS. In the past, extensive use of high ground augmented LOS. However, as the battlefield continues to become more lethal, and as emitter detection and targeting improves, the high ground will become more vulnerable. This is apparent in the continuing decline in communication site **survivability**. Although it would be folly to suggest that the high ground has no utility in the future, the above analysis suggests reliance should diminish.

A key finding of this research suggests that communications site survivability in the future may require renewed consideration. Tactical communications site selection doctrine should evolve to recognize the vulnerabilities associated with placing communications sites on the high ground. In all, the principles of communications don't change. Communicators must continue to support the warfighter with a communications

system that provides **continuity**. This is accomplished on a battlefield regardless of technological changes that increase lethality.

As the battlefield becomes more lethal, due to technological advances, communicators will have to get smarter. The findings of this research suggest that the high ground will have diminished utility in the future. The high ground is always considered first in maximizing communications range and LOS, however, opponents recognize this fact and will be capable of effectively targeting it. Technological advances in emission detection is the primary reason for this. Communicators can anticipate emitter detection, targeting, and engagement to occur more rapidly in the future. The challenge is to establish communications sites that reduce the probability of enemy interception, but still provide for **continuity**. To **survive** on the battlefield while providing for **continuity**, tactical communications sites should consider the high ground less and look to technological advances to circumvent the need for it. While technology can provide the tools to accomplish this, doctrine should follow suit to implement them.

While exploiting technology advances and adapting doctrine will be relatively easy, supplanting the high ground mental model will not. As Senge says in The Fifth Discipline, “Learning that changes mental models is...challenging...disorienting [and]...can be frightening as we confront cherished beliefs and assumptions.”<sup>48</sup>

Like Prometheus, tactical communications has been chained to the mountain. The affect of the RMA, unlike Hercules, does not appear to “free” tactical communications from the high ground. What the RMA does do, is increase the length of the chain allowing tactical communication site selection flexibility. This research suggests

reducing dependence on high ground is a concept that should be instilled in signals providers now.

## ENDNOTES

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<sup>1</sup> Thomas Bulfinch, Bulfinch's Mythology. (New York: Crown Publishers, Inc., 1974), 12-18.

<sup>2</sup> Lisa Alley, "Chief of Signal Dedicates Regimental Painting in Series," Army Communicator. Vol. 21, No. 1 (Winter 1996): 16. For terrain maps of Little Round Top see George B. Davis, The Official Military Atlas of the Civil War. (New York: Fairfax Press, 1983), plate XL, no. 2. For a description of the action see Alfred H. Guernsey, Harper's Pictorial History of the Great Rebellion, Part 2. (Chicago IL: McDonnell Bros, 1868), 509.

<sup>3</sup> US Department of the Army, Field Manual 101-5 Staff Organizations and Operations (Washington DC: Government Printing Office, 31 May 1997), 1-1:1-2 for Command, 1-2 for Control.

<sup>4</sup>Ibid., 1-2.

<sup>5</sup> US Department of the Army. FM 5-33 Terrain Analysis, (Washington, DC: Government Printing Office, 11 July 1990) Glossary-8, LOS is defined as "intervisibility between two points located on the earth's surface."

<sup>6</sup> Kenneth C. Allard, Command, Control, and the Common Defense, (New Haven, CT: Yale University Press, 1990) 37:38.

<sup>7</sup> Martin Van Creveld, Command in War, (Cambridge, MA: Harvard University Press, 1985) 62:102. There was a long range strategic optical link called the Chappe telegraph which provided connectivity from Paris to the army in the field (p. 62).

<sup>8</sup> Allard, 61.

<sup>9</sup> Irwin Rommel, Attacks, (Provo, UT: Athena Press Inc., 1979). Rommel describes the use of land line communications throughout his book. An example of wire communications in the southern theater is found in his recalling of Mount Cosna, page 175.

<sup>10</sup> John Keegan, Guderian, (New York, NY: Ballantine Books, Inc., 1973) 6, 42, 49-50.

<sup>11</sup> Heinz Guderian, Panzer Leader, (Washington DC: Zenger Publishing Co., 1979) 31.

<sup>12</sup> David L. Woods, A History of Tactical Communications Techniques, (Orlando, FL: Martin Marietta Corp., 1965) 232.

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<sup>13</sup> Thomas M. Rienzi, Vietnam Studies, Communications-Electronics 1962-1970, (Washington, DC: DA, US Government Printing Office, 1972; reprint, 1983), 142, 148.

<sup>14</sup> For the Battle of Hastings see Don Hollway, "High Ground at Stake", Military History vol. 9, no. 3 (August 1992): 50-64. For the Battle of the Falklands see Max Hastings and Simon Jenkins, The Battle for the Falklands, (New York, NY: W.W. Norton & Co., 1983), 285-314.

<sup>15</sup> Van Creveld, 10, 95.

<sup>16</sup> US Department of the Army, FM 11-64 C-E Fundamentals: Transmission Lines, Wave Propagation, and Antennas, (Washington, DC: Government Printing Office, June 1985). 1-3 presents the pebble and water analogy although the author has modified it. The FM goes on to state there are three wave propagations (sky, space/direct, and surface/ground, 2-11). The author contends that the direct wave has the least degradation to propagation of the three.

<sup>17</sup> US Department of the Army, FM 11-43 The Signal Leader's Guide, (Washington, DC: Government Printing Office, June 1995), 1-3 to 1-4.

<sup>18</sup> US Department of the Army, FM 24-1 Signal Support in the AirLand Battle, (Washington, DC: Government Printing Office, June 1995), 2-1.

<sup>19</sup> Ibid., 2-1 to 2-6.

<sup>20</sup> Electronic mail to Chief of Leadership Development Division, US Army Signal Regimental Officer Academy, Ft Gordon GA, 1 Sep 97. Author's request for information on how the Signal Corps teaches signal site selection to SOBC and SOAC. The respondent was the Chief of Leadership Development (Ms Judy W. Quattlebaum). Ms Quattlebaum's response on 5 Sep 1997, was to review FMs 11-43, -30, -37, -38, -32, -45 (DRAFT), -50, and 41. No other information was provided.

<sup>21</sup> Michael J. Mazarr, The Revolution in Military Affairs: A framework for Defense Planning, (Carlisle Barracks, PA: SSI, US Army War College, 10 June 1994), 2.

<sup>22</sup> Alvin and Heidi Toffler, War and Anti-War Survival at the Dawn of the 21st Century, (New York: Little Brown and Company, 1993), 5, 10, 31-32.

<sup>23</sup> Steven Metz and James Kievit, The Revolution in Military Affairs and Conflicts Short of War, (Carlisle Barracks, PA: SSI, US Army War College, 25 July 1994), 1.

<sup>24</sup> Mazarr, 2, and James Blaker, "Understanding the Revolution in Military Affairs," ROA National Security Report (May 1997): 23.

<sup>25</sup> John Keegan, A History of Warfare, (New York: Alfred A. Knopf, Inc., 1993), 248.

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<sup>26</sup> Ernest R. and Trevor N. Dupuy, The Encyclopedia of Military History, (New York: Harper & Row, Publishers, 1970), 17.

<sup>27</sup> Van Creveld, 41.

<sup>28</sup> Ibid., 96.

<sup>29</sup> Dupuy, 90.

<sup>30</sup> Ibid., 97.

<sup>31</sup> Keegan, 397.

<sup>32</sup> Dupuy, 611.

<sup>33</sup> Van Creveld, 60.

<sup>34</sup> Ibid., 60-61.

<sup>35</sup> Ibid., 87.

<sup>36</sup> Jeffrey R. Cooper, Another View of the Revolution in Military Affairs, (Carlisle Barracks, PA: SSI, US Army War College, April 1994), 14.

<sup>37</sup> Ibid.

<sup>38</sup> Keegan, Guderian, 8.

<sup>39</sup> TRADOC PAM 525-5, 2-7.

<sup>40</sup> Toffler, 64-65.

<sup>41</sup> Macgregor indicates deep strike precision weapons is the primary (page 44). Quotation reflects TRADOC PAM 525-5, 2-7.

<sup>42</sup> Ibid., 45.

<sup>43</sup> Clarence A. Robinson, "Joint Spectrum Center Eases Foxhole Frequency Allocation," Signal, vol. 51., no. 6 (February 1997): 59.

<sup>44</sup> Clarence A. Robinson, "High-Capacity Aerial Vehicles Aid Wireless Communication," Signal, vol. 51, no. 8 (April 1997): 16.

<sup>45</sup> Marilyn McAllister and Samuel Zabrdac, "High-altitude-endurance UAVs pick up communications node," Army Communicator, vol. 21, no. 2 (Spring 1996): 21-22. Note: multiband refers to the capability of providing communications payloads to support several bands (e.g., FM, VHF, or UHF); multimode refers to the ability to act in several

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modes (e.g., retransmission station, relay, or direct link); crosslinking is the ability of a UAV to communicate with other UAVs.

<sup>46</sup> Jacob Z. Schanker, Meteor Burst Communications, (New York: Artech House Inc., 1991), see chapters 1 and 2.

<sup>47</sup> For satellite communication during DS, see DOD, Conduct of the Persian Gulf War, Final Report to Congress, (Washington DC: US government Printing Office, April 1992), chapter VII.

<sup>48</sup> Peter M. Senge, The Fifth Discipline. (New York, NY: Bantam Doubleday Dell Publishing Group, Inc., 1994): xv.

## BIBLIOGRAPHY

### Books

Allard, Kenneth C. Command, Control, and the Common Defense. New haven, CT: Yale University Press, 1990.

Bellamy, Christopher. The Evolution of Modern Land Warfare: Theory and Practice. New York: Routledge, 1990.

Bellamy, Christopher. The Future of Land Warfare. New York: St. Martin's Press, 1987.

Brown, Frederick J. The US Army in Transition II: Landpower in the Information Age. Washington: Brassey's Inc., 1993.

Bulfinch, Thomas. Bulfinch's Mythology. New York: Crown Publishers Inc., 1974.

Clausewitz, Carl von. On War. Edited and Translated by Michael Howard, and Peter Paret. Princeton, NJ: Princeton university Press, 1976.

Davis, George B., Perry, Leslie J., Kirkley, Joseph W. The Official Military Atlas of the Civil War. New York: Fairfax Press, 1983 (reprint).

Delbruck, Hans. Translated by Renfroe, Walter J. History of the Art of War. Westport, CT: Greenwood Press, 1975.

Dupuy, Trevor N. Understanding War: History and Theory of Combat. New York: Paragon House Publishers, 1987.

Dupuy, Ernest R. and Dupuy, Trevor N. The Encyclopedia of Military History from 3500 BC to Present. New York: Harper & Row, Publishers, 1970.

Fuller, J.F.C. The Foundations of the Science of War. Ft. Leavenworth, KS: CGSC Press (Reprint), 1993.

Fuller, J.F.C. Generalship: Its Diseases and Their Cure. Harrisburg, PA: Military Service Publishing Company, 1936.

Guderian, Heinz. Panzer Leader. Translation. New York: E.P. Dutton, 1952. Reprint, Washington, DC: Zenger Pub Co., 1979.

Guernsey, Alfred H. and Alden, Henry M. Harper's Pictorial History of the Great Rebellion, Part 2. Chicago, IL: McDonnell Bros, 1868.

Hastings, Max and Jenkins, Simon. The Battle for the Falklands. New York, NY: W.W. Norton & Co., 1983.

Johnson, Stuart E. and Levis, Alexander H., eds. Science of Command and Control: Coping with Uncertainty. Washington DC: AFCEA International Press, 1988.

Johnson, Stuart E. and Levis, Alexander H., eds. Science of Command and Control: Part II Coping with Uncertainty. Washington DC: AFCEA International Press, 1988.

Keegan, John. Guderian. New York, NY: Ballantine Books Inc., 1973.

Keegan, John. The Mask of Command. New York, NY: Viking Penguin Inc., 1987.

Keegan, John. A History of Warfare. New York: Alfred A. Knopf, Inc., 1993.

Lind, William S. Maneuver Warfare Handbook. Boulder, CO: Westview Press Inc., 1985.

Macgregor, Douglas A. Breaking the Phalanx, A New Design for Landpower in the 21st Century. Westport, CT: Praeger Publishers, 1997.

Rockwell, James M., ed. AFCEA/SIGNAL C3I Series. Vol. 4. Tactical C3 for the Ground Forces. Washington, DC: AFCEA International Press, 1986.

Rost, Joseph C. Leadership for the Twenty-First Century. New York: Praeger, 1991.

Rommel, Irwin. Translation. Attacks. Provo, UT: Athena Press Inc., 1979.

Senge, Peter M. The Fifth Discipline. New York: Doubleday Dell Publishing, 1994.

Shanker, Jacob Z. Meteor Burst Communications. New York: Artech House Inc., 1991.

Simpkin, Richard E. Human Factors in Mechanized Warfare. Oxford: Brassey's Defense Publishers, 1983.

Simpkin, Richard E. Race to the Swift: Thoughts on Twenty-First Century Warfare. London: Brassey's Defense Publishers, 1985.

Sullivan, Gordon R. and Coroalles, Anthony M. Seeing the Elephant: Leading America's Army into the Twenty-First Century. Cambridge, MA: The Institute for Foreign Policy Analysis, 1995.

Toffler, Alvin and Heidi. War and Anti-War Survival at the Dawn of the 21st Century. New York: Little, Brown and Company, 1993.

Van Creveld, Martin. Command in War. Cambridge, MA: Harvard University Press, 1985.

Van Creveld, Martin. Supplying War. Cambridge, MA: Cambridge University Press, 1977.

Van Creveld, Martin. Technology and War. New York: The Free Press, 1989.

Van Creveld, Martin. The Transformation of War. New York: The Free Press, 1991.

#### Monographs, Essays, Papers and Theses

Bass, Charles A. Decision Loops: the Cybernetic Dimension of Battle Command.

School of Advanced Military Studies Monograph, US Army Command and General Staff College, Fort Leavenworth, KS, December, 1996.

Bornman, Louis G., Ingram Michael C., and Martin, Peter J. Information Technology in the Digitized Division. Fort Leavenworth, KS: TRADOC Analysis Center, November, 1995.

Bracken, Paul and Alcala, Raoul Henri. Whither the RMA: Two Perspectives on Tomorrow's Army. Carlisle Barracks, PA: Army War College Strategic Studies Institute, July 1994.

Cooper, Jeffrey R. Another View of the Revolution in Military. Carlisle Barracks, PA: Army War College Strategic Studies Institute, July 1994.

Colodney, Lori L.S. Getting Command and Control Systems Back into the Fight on the Digitized Battlefield. Leavenworth, KS: School of Advanced Military Studies, December 1994.

Deptula, David A. Firing for Effect: Change in the Nature of Warfare. Arlington, VA: Aerospace Education Foundation, 1995.

Department of Defense. Conduct of the Persian Gulf War, Final Report to Congress. Chapters I through VIII, Washington DC: US Government Printing Office, April 1992.

Gray, Colin S. Strategic and Combat Studies Institute, The Occasional, Number 28, The American Revolution in Military Affairs: An Interim Assessment. United Kingdom: The Strategic and Combat Studies Institute, 1997.

Howard, Sir Michael and Guilmartin, John F. Two Historians in Technology and War. Carlisle Barracks, PA: Army War College Strategic Studies Institute, July 1994.

Jablonsky, David. The Owl of Minerva Flies at Twilight: Doctrinal Change and Continuity and the Revolution in Military Affairs. Carlisle Barracks, PA: Army War College Strategic Studies Institute, May 1994.

Kahan, James P., Worley, Robert D., and Stasz, Cathleen. Understanding the Commanders' Information Needs. Santa Monica, CA: RAND Corporation, 1989.

Mazarr, Michael J. The Revolution in Military Affairs: A Framework for Defense Planning. Carlisle Barracks, PA: Army War College Strategic Studies Institute, June 1994.

Metz, Steven and Kievit, James. The Revolution in Military Affairs and Conflict Short of War. Carlisle Barracks, PA: Army War College Strategic Studies Institute, July 1994.

Metz, Steven and Kievit, James. Strategy and the Revolution in Military Affairs: From Theory to Policy. Carlisle Barracks, PA: Army War College Strategic Studies Institute, June 1995.

Romjue, John L. American Army Doctrine for the Post-Cold War. Washington DC: Center of Military History Office, US Army TRADOC, 1996.

Tilford, Earl H. The Revolution in Military Affairs: Prospects and Cautions. Carlisle Barracks, PA: Army War College Strategic Studies Institute, June 1995.

Wentz, L.K., Harris, C.H., et al, ed. L.L. Stine. Perspectives on C3I Performance in Desert Shield/Desert Storm, Annex H: Communications, McLean VA: The MITRE Corporation, October 1991.

Woods, David L. A History of Tactical Communication Techniques, Orlando, FL: Martin Marietta Corp., 1963.

#### Magazines, Articles, and Periodicals

Ackerman, Robert K. "Academia, Industry Team Up to Achieve Mobile Connectivity." Signal, 51, No. 9, (May 1997): 60-61.

Ackerman, Robert K. "Linking Forces on the Move Vexes Agency Researchers." Signal, 51, No. 9, (May 1997): 57-60.

Ackerman, Robert K. "Wireless Widgets Enable High-Speed Data, Videos." Signal, 51, No. 10, (June 1997): 73-78.

Alley, Lisa. "Chief of Signal Dedicates Regimental Painting in Series". Army Communicator. Vol. 21, No. 1 (Winter 1996): 16.

Anderson, Dean R. "Modernizing Army Command and Control." Military Review, 70, No. 7 (July 90): 2-10.

Blaker, James R. "Understanding the Revolution in Military Affairs." ROA National Security Report, (May 1997): 23-34.

Bolger, Daniel P. "Command or Control?" Military Review, 70, No. 7 (July 1990): 69-79.

Brown, Thomas E. "PW96: Insights and Observations." Military Review, 76, No. 4 (July-August 1996): 11-22.

Buchholz, Douglas. "State of the Signal Corps' Speech". Army Communicator, 21, No. 1, (Winter 1996): 2-4.

Bunker, Robert J. "Advanced Battlespace and Cybermaneuver Concepts: Implications for Force XXI." Parameters (Autumn 1996): 108-120.

Czerwinski, Thomas J. "Command and Control at the Crossroads." Parameters (Autumn 1996): 121-132.

Dessert, Rolland A. "Mobile Strike Force; An Experiment in Future Battle Command." Military Review, 76, No. 4 (July-August 1996): 34-39.

Echevarria, Antulio J. "Dynamic Inter-Dimensionality A Revolution in Military Theory." Joint Forces Quarterly, (Spring 1997): 29-36.

Farmer, Edward. "Antenna Performance for Near-Vertical-Incidence Skywave Communications." Army Communicator, 21, No. 3, (Summer 1996): 10-20.

Fiedler, David. "Cosite Interference: Force XXI Communications Roadblock." Army Communicator, 21, No. 4, (Fall 1996): 54-59.

Fiedler, David. "Tactical Ground-Wave Communications for Force XXI Tactical Internet and Beyond." Army Communicator, 21, No. 3, (Summer 1996): 21-27.

Foss, John W. "Command." Military Review 70, No. 5 (May 1990): 3-7.

Franks, Frederick M. "Battle Command: A Commander's Perspective." Military Review, 76, No. 3 (May-June 1996): 4-25.

Friend, Beverly. "Perspective: Signal Doctrine Impacts 21st Century Army." Military Review, 22, No. 2, (Spring 1997): 54-55.

Gumahad, Arsenio T. "The Profession of Arms in the Information Age." Joint Forces Quarterly, (Spring 1997): 14-20.

Joint Chiefs of Staff. "Joint Vision 2010: America's Military Preparing for Tomorrow." Joint Forces Quarterly, (Summer 1996): 34-49.

Kind, Peter A. "Army tactical C2 System." Military Review, 70, No. 9 (July 1990): 35-41.

Knudson, Wayne. "The Future of C2." Military Review, 70, No. 9 (July 1990): 18-24.

MacKenzie, Scot. "Signal Roles and Missions: Changes Loom on the Digitized Horizon of the 21st Century." Army Communicator, 21, No. 4, (Fall 1996): 13-14.

McAllister, Marilyn and Zabrdac, Samuel. "High-Altitude-Endurance Unmanned Aerial Vehicles Pick-up Communications Node." Army Communicator, 21, No. 2, (Spring 1996): 21-24.

Miller, John E. and Reitinger, Kurt C. "Force XXI Battle Command." Military Review, 75, No. 4 (July-August 1995): 5-9.

Morningstar, James K. "Technologies, Doctrine, and Organization for RMA." Joint Forces Quarterly, (Spring 1997): 37-43.

Murray, Williamson. "Innovation: Past and Future." Joint Forces Quarterly, (Summer 1996): 50-60.

Muse, Genese. "Warfighter Information Network and Doctrine's Future Issues." Army Communicator, 21, No. 4, (Fall 1996): 33-35.

Owen, William A. "The Emerging System of Systems." US Naval Institute Proceedings, (May 1995): 35-39.

Robinson, Clarence A. "Computing Advances Spark Spectrum Management Tools." Signal, 51, No. 6, (February 1997): 55-58.

Robinson, Clarence A. "High Capacity Aerial Vehicles Aid Wireless Communications." Signal, 51, No. 8, (April 1997): 16-20.

Robinson, Clarence A. "Joint Spectrum Center Eases Foxhole Frequency." Signal, 51, No. 6, (February 1997): 58-59.

Robinson, Clarence A. "Mobile Military Units Embrace Digital Data, Vehicle Tracking." Signal, 51, No. 9, (May 1997): 53-54.

Schneider, James J. "Black Lights: Chaos, Complexity, and the Promise of Information Warfare." Joint Forces Quarterly, (Spring 1997): 21-20.

Schneider, James J. "The Theory of the Empty Battlefield." JRUSI (September 1987): 37-44.

Shalikashvili, John M. "A Word from the Chairman." Joint Forces Quarterly, (Summer 1996): 1, 4-5.

Shalikashvili, John M. "A Word from the Chairman." Joint Forces Quarterly, (Winter 1996-1997): 1, 4-6.

Stavridis, James. "The Second Revolution." Joint Forces Quarterly, (Spring 1997): 8-13.

Wass de Czege, Huba "Mobile Strike Force: A 2010 potential Force." Military Review, 76, No. 4 (July-August 1996): 70-84.

#### Military Manuals and Documents

US Department of the Army. Army Training and Evaluation Program 11-1 Signal Training and Evaluation Outlines. Washington DC: US Government Printing Office, 6 October 1994 (Coordinating Draft).

US Department of the Army. Army Training and Evaluation Program 11-2 Signal Common Training and Evaluation Outlines. Washington DC: US Government Printing Office, 6 October 1994 (Coordinating Draft).

US Department of the Army. Field Circular 71-6 Battalion and Brigade Command and Control. Washington DC: US Government Printing Office.

US Department of the Army. Field Manual 5-33 Terrain Analysis. Washington DC: US Government Printing Office, 11 July 1990.

US Department of the Army. Field Manual 11-30 MSE Communications in the Corps/Division. Washington DC: US Government Printing Office, 27 February 1991.

US Department of the Army. Field Manual 11-32 Combat Net Radio Operations. Washington DC: US Government Printing Office, 15 October 1990.

US Department of the Army. Field Manual 11-37 MSE Primer for Small-unit Leaders. Washington DC: US Government Printing Office, November 1990.

US Department of the Army. Field Manual 11-38 MSE System Management and Control. Washington DC: US Government Printing Office, 4 April 1991.

US Department of the Army. Field Manual 11-41 Signal Support: Echelons Corps and Below (ECB). Washington DC: US Government Printing Office, 18 December 1991.

US Department of the Army. Field Manual 11-43 The Signal Leader's Guide. Washington DC: US Government Printing Office, June 1995.

US Department of the Army. Field Manual 11-50 Combat Communications within the Division (Heavy and Light). Washington DC: US Government Printing Office, 4 April 1991.

US Department of the Army. Field Manual 11-55 Mobile Subscriber Equipment. Washington DC: US Government Printing Office, (Draft).

US Department of the Army. Field Manual 11-64 C-E Fundamentals: Transmission Lines, Wave Propagation, and Antennas. Washington DC: US Government Printing Office, June 1985.

US Department of the Army. Field Manual 11-65 High Frequency Radio Communications. Washington DC: US Government Printing Office, October 1978.

US Department of the Army. Field Manual 11-75 Battlefield Information Services. Washington DC: US Government Printing Office, 20 September 1994.

US Department of the Army. Field Manual 11-486-1 Telecommunications Engineering Planning Considerations. Washington DC: US Government Printing Office, June 1978.

US Department of the Army. Field Manual 24-1 Signal Support in the AirLand Battle. Washington DC: US Government Printing Office, October 1990.

US Department of the Army. Field Manual 24-7 Army Battle Command System Systems Management. Washington DC: US Government Printing Office, June 1995.

US Department of the Army. Field Manual 24-19 Radio Operator's Handbook. Washington DC: US Government Printing Office, May 1991.

US Department of the Army. Field Manual 24-24 Signal Data Reference: Signal Equipment. Washington DC: US Government Printing Office, 29 December 1994.

US Department of the Army. Field Manual 24-32 Tactics Techniques and Procedures for the Tactical Internet Brigade and Below. Washington DC: US Government Printing Office, 28 October 1996 (Draft)

US Department of the Army. Field Manual 24-41 Tactics Techniques and Procedures for the Enhanced Position-Location Reporting System. Washington DC: US Government Printing Office, 4 October 1996 (Draft)

US Department of the Army. Field Manual 101-5 Staff Organization and Operations. Washington DC: US Government Printing Office, May 1997.

Training and Doctrine Command. TRADOC Pamphlet 525-5 Force XXI Operations. Fort Monroe, VA: US Government Printing Office, August 1994.

US Department of the Army. Technical Manual 11-666 Antennas and Radio Propagation. Washington DC: US Government Printing Office, February 1953.

US Department of the Army. Vietnam Studies, Communications-Electronics 1962-1970. Washington DC: US Government printing Office, 1972.